DEPARTMENT OF OCEANOGRAPHY
UNIVERSITY OF WASHINGTON

Technical Report No. 26

MICROSALINOMETER FOR OCEANOGRAPHIC MODEL STUDIES

Office of Naval Research
Contract N8onr-520/III
Project NR 083 012

Reference 54-10
March 1954

SEATTLE 5, WASHINGTON

UNIVERSITY OF WASHINGTON DEPARTMENT OF OCEANOGRAPHY
(Formerly Oceanographic Laboratories)
Seattle, Washington

MICROSALINOMETER FOR OCEANOGRAPHIC MODEL STUDIES

by

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Clifford C. Barnes
for Richard H. Fleming
Executive Officer

ABSTRACT

An instrument has been developed for determining salinity structure in a small scale oceanographic model of Puget Sound. Variations in electrical conductivity with depth at any point in the model are measured with a small probing conductivity cell. The conductivity-depth diagram is traced by an oscilloscope and photographed. Response to changes in conductivity is of the order of 0.01 second. The present accuracy of measurement is about 1%.

With suitable modifications the instrument may be adapted to almost any scale model. Adaption to use for rapid salinity determination of sea water samples where titration accuracy is not required has been suggested.

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INTRODUCTION

An oceanographic model of Puget Sound has been constructed at the Department of Oceanography, University of Washington (1), as an aid in studying the structure and movement of the water. The horizontal and vertical scales selected were 1.84 inches per nautical mile (1:40,000), and 1/16 inch per fathom (1:1,152), respectively. This resulted in a time scale of 3.055 seconds per hour.

Of primary importance in the oceanography of Puget Sound is the salinity structure resulting from the mixing of inflowing salt water from the Pacific Ocean with river runoff. To determine this structure in the model, it was necessary to devise an instrument for determining, quickly and reliably, the salt concentration at all depths at selected locations. The small model scales used required that the instrument be able to resolve and record significant variations in salt concentrations within very small increments of depth with minimum disturbance of the water structure.

Methods investigated for determining the salinity structure in the model included the photometric determination of the concentration of a dye added in known ratio in either the river water or the salt water. This method was rejected because of the bulkiness of the sensing element and poor depth discrimination. The use of silver-silver chloride concentration cells in the form of either a probe or fixed installations showed some promise at first, but the difficulty of attaining reproducibility and matching of the cells resulted in rejection of this

method. The method finally adopted is based upon the conductivity of the water.

CONSTRUCTION

The salinity indicating instrument, as constructed, is essentially a probing conductivity cell coupled to an oscilloscope. Water is drawn through the cell during the probing cycle and a curve closely approximating a plot of conductivity versus depth is traced on the cathode-ray tube. This curve, traced on the downstroke of the probe and a zero conductivity trace produced on the return, is photographed for a permanent record.

A number of cell designs were tried. Two-electrode cells were found to be unsuitable because of electrical interference. A symmetrical three-electrode cell was found less susceptible to 60-cycle pickup. Final design is shown in Figure 1. The electrodes were made from 1/8 inch silver alloy wire (Easy Flo silver solder). The two end electrodes, 1/8 inch in length, and the center electrode $\frac{1}{4}$ inch in length were drilled longitudinally with a #72 drill (0.025 inch). Copper leads were then soldered to each electrode. Holes were drilled in each end of two one-inch lengths of $\frac{1}{4}$ inch diameter Lucite rod to receive the electrodes. After the electrodes had been pressed into position in the plastic sections, the capillaries were drilled between them, thereby insuring perfect alignment. After cementing the two halves together, the cell was attached to a length of $\frac{1}{4}$ inch o.d. plastic tube which acts as a support and through which the water is drawn by means of an aspirator. The tubing was grooved on the outside to enable the leads from the electrodes to be imbedded in the plastic for

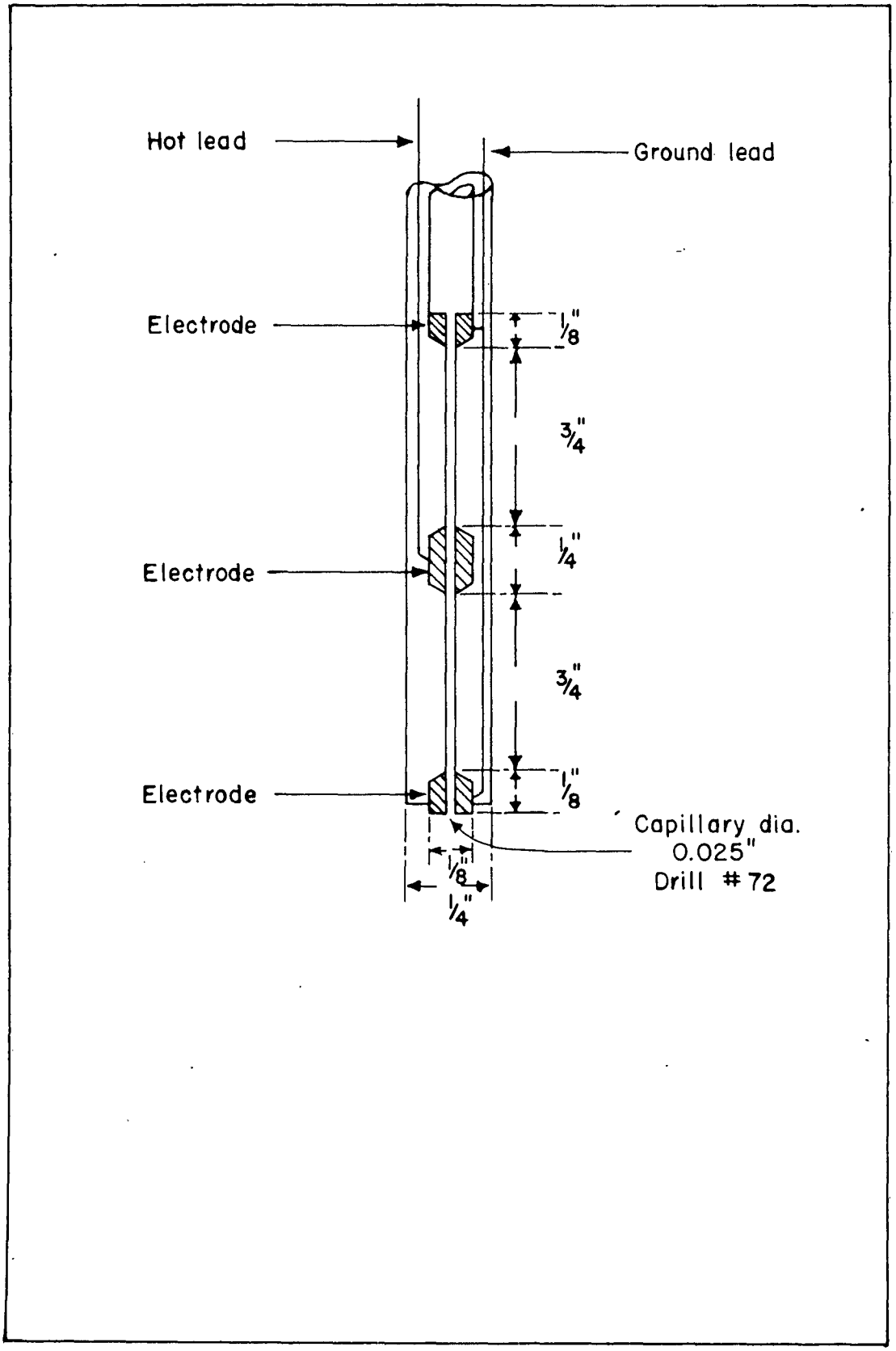

FIGURE 1. Design of conductivity cell.

insulation.

The probe is lowered and raised by an air cylinder controlled by a reversing valve. For each sampling cycle, the valve is actuated manually to start the cell lowering. Upon reaching a preset depth, reversal is automatic and the cell is raised until it is out of the water. Operating speed is controlled by a needle valve in the air supply. A simplified drawing of the mechanism is shown in Figure 2.

The electrical circuits of the instrument embody some principles not ordinarily used in conductivity measurements. A schematic diagram of the oscillator, amplifier, and detector circuits is shown in Figure 3.

The oscillator supplies current to the conductivity cell at a frequency of 10,000 cycles and potentials variable up to 19 volts. Regulation of the output is achieved by means of voltage regulation in the plate supply of the oscillator which, coupled with the low impedance of the output transformer, provides a relatively stable voltage source.

Measurement of the cell conductance could have been accomplished by determining the unbalance voltage of a Wheatstone bridge. However, it was sufficiently accurate and more direct to measure the electrical current flowing through the cell which, at constant voltage, is directly proportional to the conductance. The current is determined from the voltage drop across a precision 47-ohm resistor in series with the cell. Since this resistor is at most about 0.02 of the cell resistance, it has little effect upon the linearity of the circuit. This voltage is then amplified by a single stage RC amplifier and rectified by an infinite impedance detector having an additional filter network in the output circuit. The detector output is applied to the X-axis of the

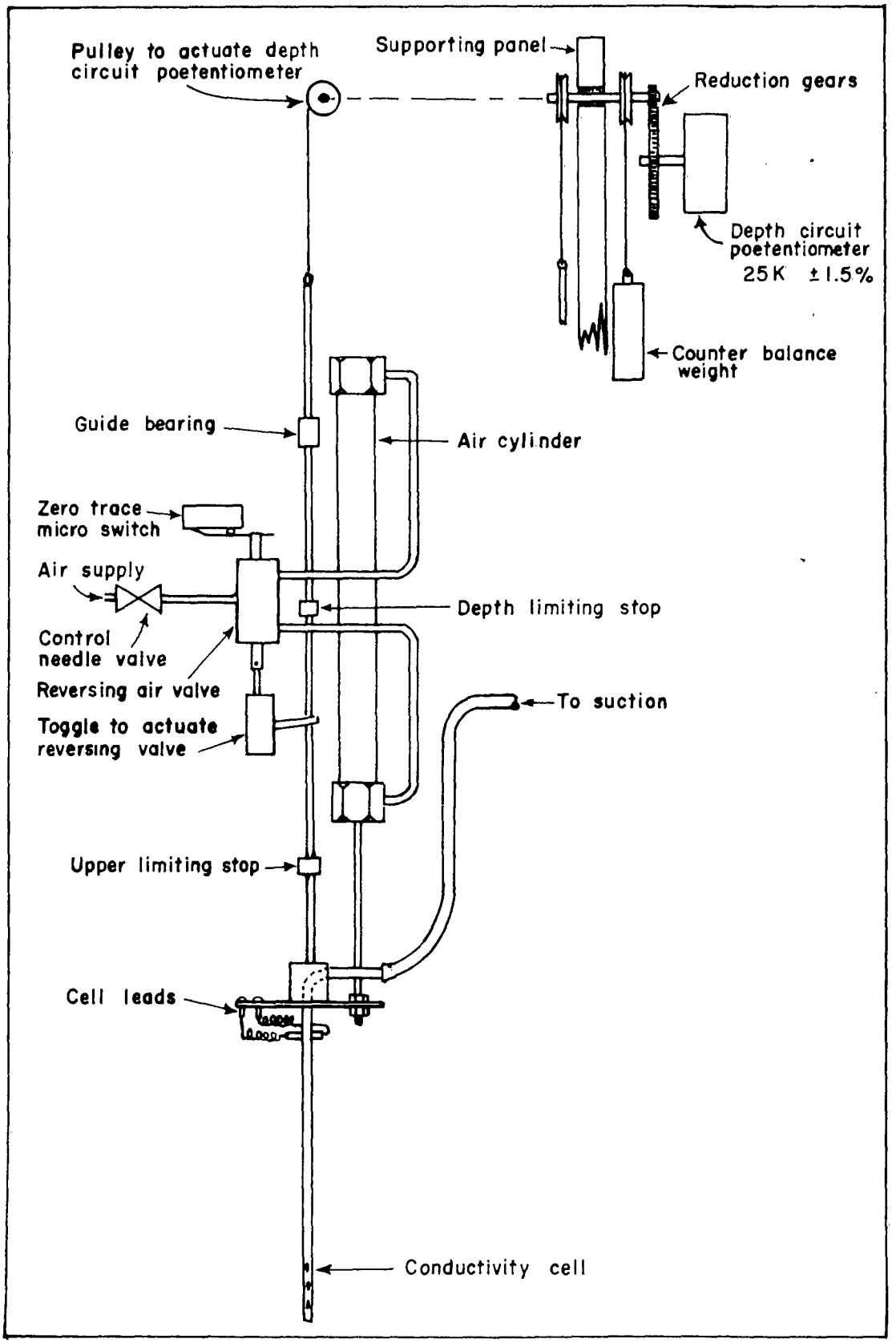

FIGURE 2. Functional diagram of the probing mechanism.

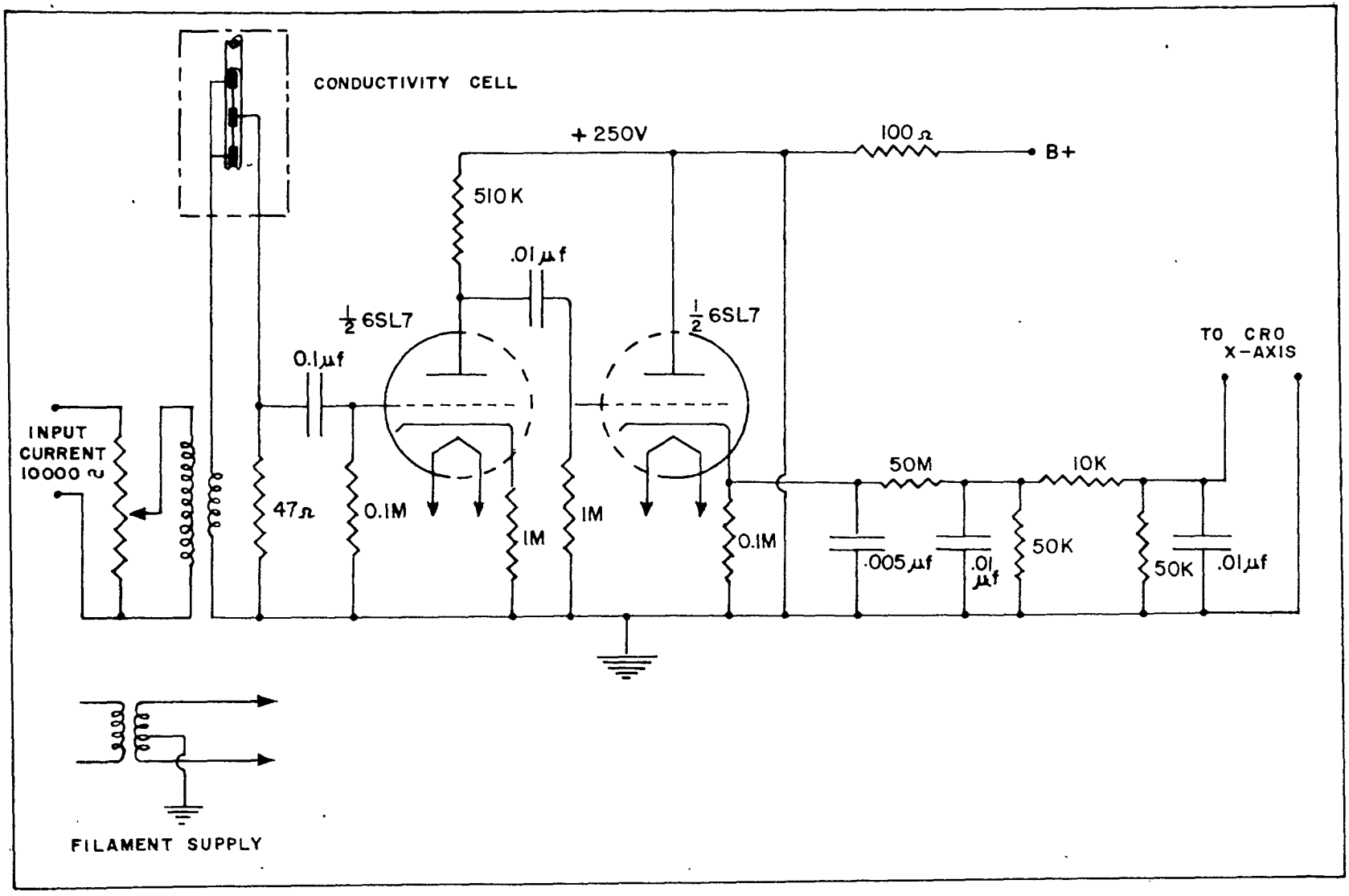

FIGURE 3. Schematic diagram of the amplifier-detector circuit.

oscilloscope. A potential divider in the power supply and a precision linear potentiometer actuated by the raising and lowering mechanism of the probe provide a DC voltage which varies with the vertical position of the probe. This voltage is applied to the Y-axis of the oscilloscope; thus a plot of output voltage versus depth is produced on the face of the tube. A switch, actuated by the reversing air valve, opens the cell circuit during the upward travel of the probe to eliminate the return conductivity trace and provide a reference zero conductivity trace.

To facilitate adjustment of the instrument, a calibrated precision resistor of 8020 ohms may be switched into the cell position in the circuit. This permits the gain on the oscillator and on the oscilloscope to be adjusted to a reproducible standard "calibration deflection." Operation of the instrument in several salinity ranges is possible by adjustment to suitable calibrating deflections. Accurately-machined blocks provided a means of controlling vertical travel of the probe mechanism for direct calibration of the depth scale.

The oscilloscope used was a Dumont Type 304-H which later was modified for use with a flat-faced tube. Marked curvature of the photographed trace existed with the conventional tube. These effects, although minimized by calibration and by working as near the center of the tube face as possible, were undesirable. Installation of the flat-faced tube largely corrected these difficulties. The d. c. amplifiers show a noticeable drift in zero deflection, but the gain is stable within the error of reading over a period of at least a day. Since the line corresponding to zero conductance appears on each trace, a ready reference exists to correct for zero drift.

SENSITIVITY AND ACCURACY

The accuracy of the system exclusive of the cell and oscilloscope was determined by the substitution of calibrated wirewound resistors, ranging from 3,500 ohms to 100,200 ohms, for the cell and a Leeds & Northrup Type K precision laboratory potentiometer for the oscilloscope. The resulting relation found between output voltage of the detector and the calculated conductance is presented in Figure 4. Although not strictly linear over large ranges of conductance, the relation is sufficiently so over the small ranges usually studied. Lack of linearity is due principally to impedance in the oscillator output circuit and could be improved markedly by simple changes.

Similarly the cell constant, determined by drawing sea water samples of known chlorinity and temperature, was found to be 177.9 cm with a standard deviation of $\pm$0.5 cm in the Cl range 15 to 16°/oo. The specific conductivity of the samples was determined from the tables of Thomas, Thompson, and Utterback (2).

The current density in the cell is such that the temperature tends to rise at a rate of about 0.6° C. per second. When water is drawn through the cell at the usual rate of 40 cc. per minute, the cell volume is replaced in 0.028 second and the average temperature in the cell is increased about 0.008° C. Temperature changes of this amount or less are below the sensitivity of normal operation.

DEPTH RESOLUTION

The depth resolution depends upon the response time and the rate of lowering of the probe. The response time of the system to the step change at the surface of the water was determined and found to be 90%

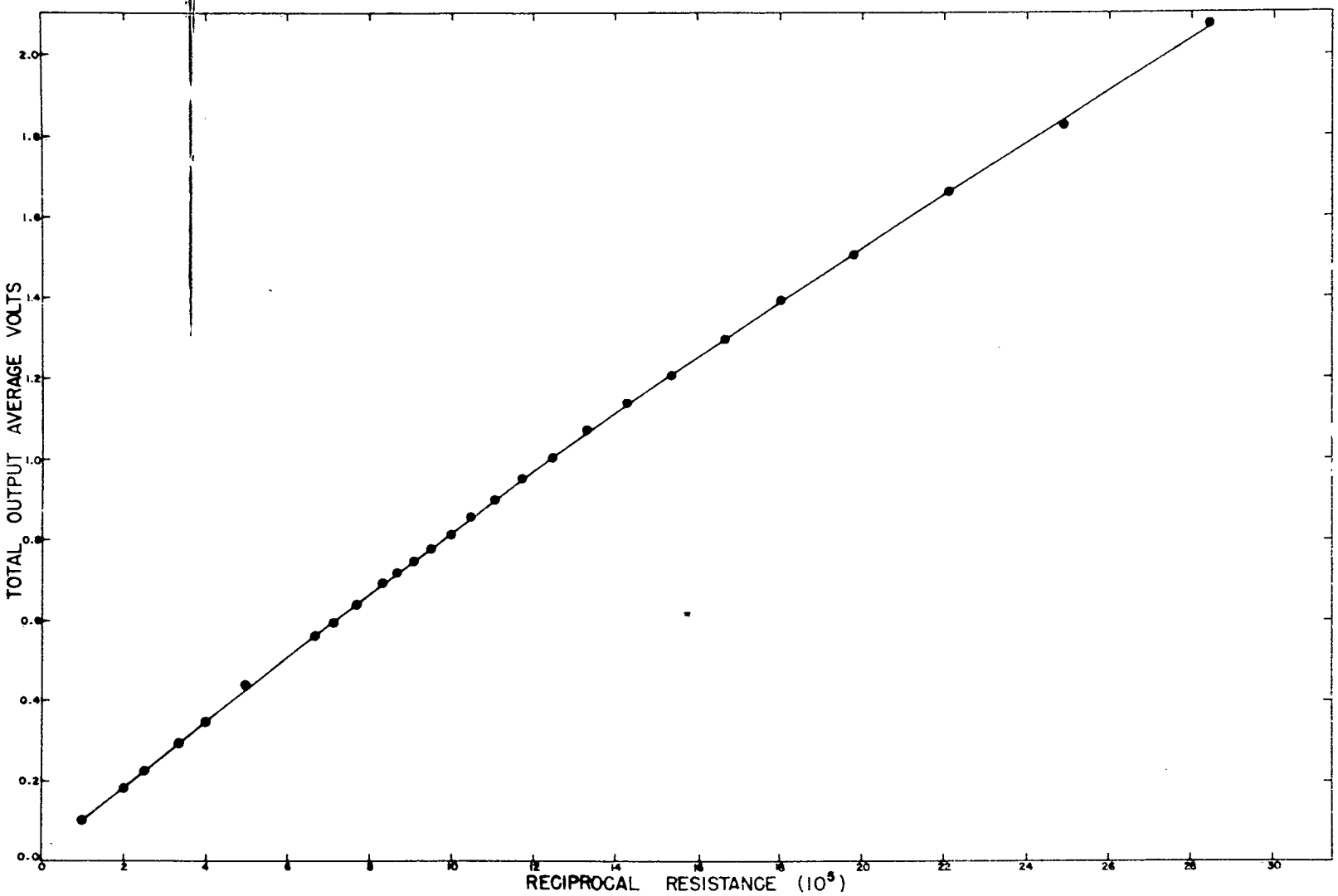

FIGURE 4. Detector Output as a Function of Conductance.

in 8 microseconds. This time is determined principally by the flushing rate since the electrical response time of the circuit was 2 microseconds. It would appear that the initial filling of the cell upon reaching the water surface is more rapid than the calculated filling time based upon a flow of 40 cc. per minute. However, it is apparent that the response is a function of the flushing rate. When the probe is lowered at the rate of 3 to 4 inches per second ordinarily used, it will travel a distance equivalent to about 10 feet during the calculated filling time of the cell of 0.028 seconds. To a degree the precision can be increased by lowering more slowly. However, the limiting factor in the depth measurement is associated with the manner in which the water is sucked into the cell.

PROBING ACTION

The effect of the probing action of the conductivity cell on the structure of the water was studied by observing its travel through a sharp interface of a two-layer fresh- and salt-water system (see Figure 5). Under normal operating conditions, passage of the probe through the system appears to cause no significant disturbance at the cell tip during lowering. The greatest mixing or disturbance of the system occurs from the surface drag or skin friction of the probe. During the downward travel, a thin skin of the upper layer is carried into the lower layer by the exterior of the probe. This mixed water tends to rise. Upon reversal of direction, the heavier lower water begins to be carried upward, sloughs off the probe and sinks. Since water is being drawn into the cell continuously, at least part of the mixed water is removed. When the probe was observed operating without suction, the

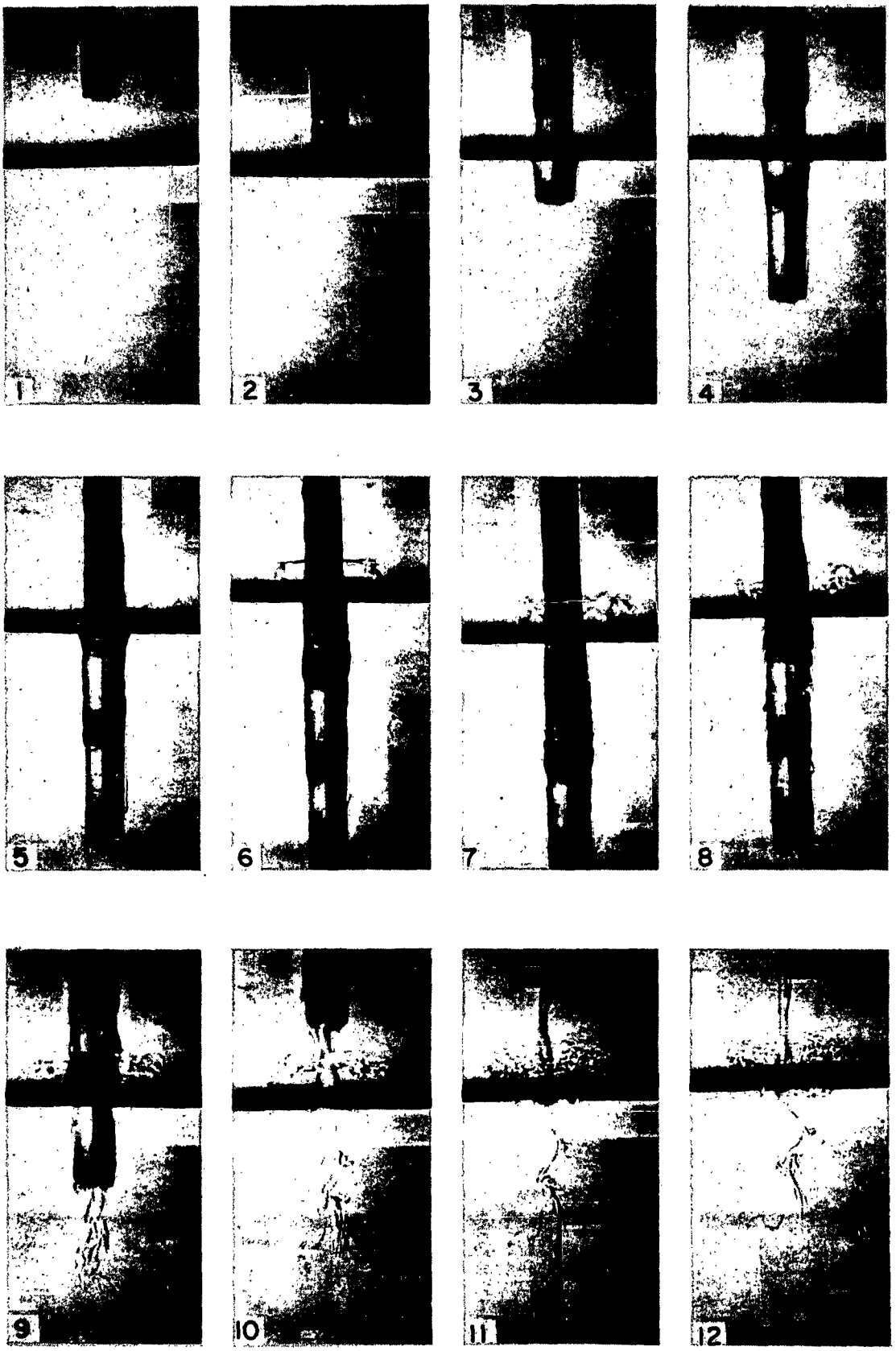

FIGURE 5. Photographs of the probe passing through a sharp interface.

mixing was markedly increased.

Photographs of the cell action show that water is drawn into the cell in a very small diameter vortex extending about 0.1 inch or less ahead of the tip. The presence of the vortex leads to an uncertainty as to the precise depth from which the sample is beimg drawn. On the basis of the observed length of the vortex, it appears to be about the same as the depth resolution computed from the flushing rate of the cell and rate of lowering as given above.

CALIBRATION

It was desirable to be able to correlate directly the conductivity in terms of salinity to simplify the data. Since the temperature of the water in the model is not controlled other than by room temperature, the water is essentially isothermal in structure but may vary slightly from day to day. Temperature corrections for the calibration were therefore necessary. Calibration of the instrument consisted of determining the beam deflection on the oscilloscope with the cell drawing standard salt solutions at known temperatures within the desired range. Since the beam deflection is a function of the gain setting on both amplifier and oscilloscope, the ratio of sample deflection over calibration deflection is obtained rather than the actual conductance. This ratio is used to correct for minor changes in the calibration deflection. Where large changes are made for the purpose of changing the salinity range, a change in the calibrating resistor is desirable.

A calibration curve plotted as deflection ratio versus salinity at constant temperature is shown in Figure 6.

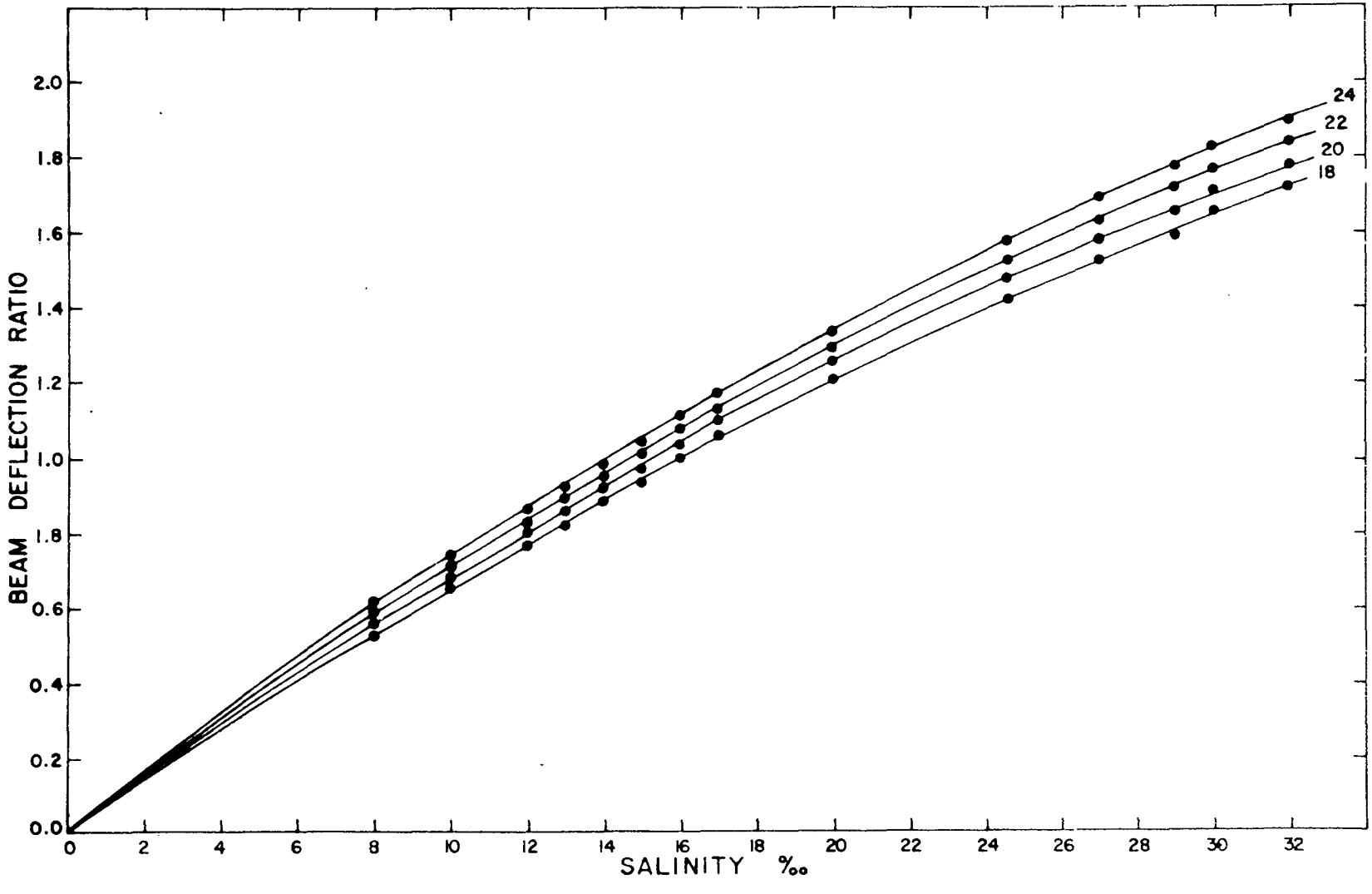

FIGURE 6. Calibration Curve.

OPERATIONAL PROCEDURE

The procedure for adjustment and operation of the instrument is as follows:

1. Set the gain controls on the oscillator-amplifier-detector unit and the Y-axis gain and position controls on the oscilloscope, so that the range of salinity to be measured is appropriately represented within the limits of the tube face.
2. Adjust the gain and position controls of the X-axis of the oscilloscope for the depth scale desired.
3. Photograph the deflection caused by the standard calibrating resistor.
4. Locate the probing mechanism at the station to be sampled and adjust the depth limiting stop to the sampling depth.
5. Proceed to probe as desired, photographing the trace where a permanent record is required. Allow sufficient time between probing cycles to allow the water structure to recover or the mixed water to be moved by tidal action.
6. Measure the water temperature at intervals depending upon variance.

The photographed traces are read by measuring the deflection from the zero trace and expressing the results as multiples of the deflection ratio obtained with the standard resistor. Salinity values are obtained from the calibration curve of deflection ratio versus salinity.

The trace was photographed using a Robot camera and Eastman Super XX 35 mm. film with short time exposures covering the entire probing cycle. An extension tube was made to allow a camera-to-tube distance of 8 inches to be used, thereby utilizing the entire frame.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Mr. Charles C. Andrew for his assistance in the design and construction of the oscillator, amplifier-detector unit.

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